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Habitat template for invertebrates on granite outcrops

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Abstract

This study considers the known occurrences of invertebrate taxa from granite outcrops of southern Western Australia. The microhabitats occupied are briefly described. A schematic habitat template for composite outcrop configurations is presented. Only "ground" living or those directly associated with rock surfaces and aquatic taxa are considered. Rock flakes (exfoliated slabs) and rock pools have the richest taxonomic representation. These habitats, and moss swards, are also the most vulnerable to human induced disturbance. Seepages, from certain moss beds and meadows are important for retaining relictual taxa. The anomaly of confinement to isolated rocks of geographically widespread species is posed. Conversely, certain ancient genera are believed to have speciated around rocks following isolation associated with onset of arid conditions in the surrounding landscape.

Keywords: granite outcrops, climatic change, endemicity, species inventory, microhabitat, water capture, conservation

Introduction

Granite outcrops are salient features across south-western Australia from the Darling Scarp eastward to Eyre Peninsula. Within this broad geographic area, the southern part of Western Australia forms the focal region of the following discussion, which has relevance also for granite exposures in other regions of Australia. People have used the outcrops ever since they first arrived on the continent, primarily as a water source. Aborigines used the rocks as campsites and took advantage of the natural water holes, which were carefully maintained and frequently safeguarded from disturbance by animals and pollution. In contrast, the first Europeans who included nomadic pastoralists quickly modified such water sources by constructing simple wells and dams for use by both humans and stock (Main 1993). Associated with later agricultural settlement and the development of railway networks, large storage dams and tanks were constructed at the base of rocks or across natural configurations of rock topographies (see Laing & Hauck 1997, for review). At the same time exfoliated rock slabs were cemented into walls across the surface of rocks (Plate 1), thereby diverting rainwater from the natural catchment surface and drainage directions. Inevitably, such modifications have had an impact on the biology and diversity of invertebrates, sometimes favourably *e.g.* by increasing habitat resources for some aquatic organisms such as dragonfly larvae, water mites and small crustaceans. However, the overall impacts have been deleterious, particularly for terrestrial invertebrates.

This paper discusses the range of habitats (presented as a template) provided by granite outcrops, that are occupied by invertebrates. It gives an inventory of predominant taxonomic groups so availed, indicates the principal hazards introduced by European usage and how they affect the invertebrate fauna, and promotes a management ideal of salvage and restoration.

Topography and provision of a habitat template

The general image of a granite outcrop is either as an exposed rock pavement or more usually a single dome (monadnock or inselberg (Jutson 1934; Prider 1957, 1985); tor (Main 1967)), or as a complex of such exposures. The outcrops, emerging out of an otherwise subdued or gradually elevated landscape, may be low and platform-like or high with precipitous slopes including "waves" or flared edges. While Twidale *et al.* (1999) suggest that "tor" is perhaps inappropriately used in Western Australia due to it being "increasingly" recognised as "a regional British term", it is arguable to retain the term as understood here in application to either domical outcropping structures or to large boulders, because of its long use in Western Australia from the time of coastal exploration by Vancouver in 1791-2 (Vancouver 1801).

Whether domes (bornhardts of Campbell 1997 and Twidale & Bourne 1998) or platforms, the exposures are variously eroded to form many surface features. Campbell (1997, Table 1) categorised many landforms of granite according to their weathering, constructional and tectonic forms. Main (1997) gave a simplified classification of rocks pertaining to their biological associations as domes, pavements, sub-surface *i.e.* "fugitive" outcrops and boulder piles or "tumuli" (nubbins" of Campbell 1997 and Twidale & Bourne 1998). In this context, the term "tumulus" for a rocky mound was meant figuratively and in no way intended to indicate human construction or rearrangement (*e.g.* a rock lined sepulchral mound or barrow) as interpreted by Twidale *et al.* (1999). Nevertheless because of the possibility of a literal interpretation of my usage, and whether a "nubbin" or not, "rock pile" or "boulder pile" or "rocky hillock" may be more appropriate.

The following examples include most of the erosional features that provide habitats for invertebrates (see also Bayly 1997, 1999; Hussey 1998; Main 1967, 1997). The

HABITATS OF INVERTEBRATES

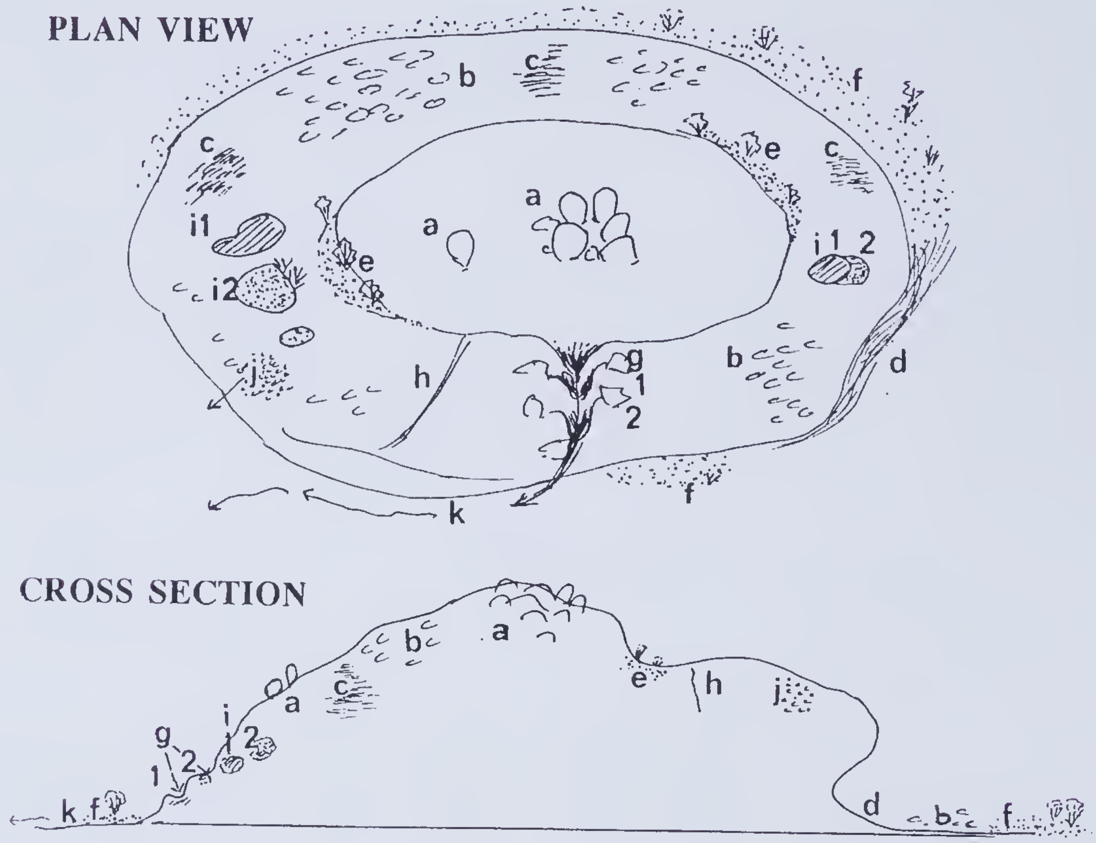

Figure 1. Habitats for invertebrates provided by a granite outcrop. See Table 1 for records of fauna observed in, recorded or collected from respective microhabitats. **Terrestrial**: **a**, rock piles, pedestals; **b**, rock flakes and slabs (partially exfoliated slabs); **c**, lichen, moss swards; **d**, flares or "waves"; **e**, shelves with shrubs and meadow; **f**, apron or peripheral meadow; **g**, tiers of depressions, **g 2**, "Babylonian gardens"; **h**, crevices; **i, 2** seral meadows. **Aquatic**: **g**, tiers of depressions, **g 1**, "water falls" and stepped pools or gnammas; **i 1**, rock pools or gnammas; **j**, runoff seeps from moss and soil (and "streams"); **k**, peripheral streams (at edge of rock), creeks.

topographic position of these respective habitats on granite outcrop configurations is indicated in Fig 1.

Terrestrial habitats

(a) Pedestals, rock piles and tafoni; boulder shadows. Single boulders with narrow bases (pedestal rocks) are frequently sited on the slopes of domical rocks. Rock piles may be sited on the tops or slopes of outcrops or sometimes on hillocks and often comprise loose groups of boulders partly buried in soil. Tafoni are hollowed-out boulders resembling small, partly open caves. These habitats provide shelter for invertebrates amongst the soil and debris at the base of the rocks; shadow areas also are amenable to invertebrate occupation.

(b) Rock flakes and slabs. These are formed by exfoliation from the parent rock and form permanent or temporary living spaces between the parent rock surface and roof of the flakes. Undisturbed outcrops are generally littered with numerous slabs (Plate 2) but on many outcrops they have been collected and cemented into walls to divert water from the natural catchment slopes (Plate 1) thereby causing habitat deprivation. Small sheets of partly exfoliated rock are an earlier developmental stage to free slabs or flakes; large, partly attached sheets form "A-Tents" (Campbell 1997) and harbour invertebrates.

(c) Lichen and moss swards. These grow wherever a rock surface has weathered and soil has formed. Such mats may be small (a few centimetres) or extensive. If favourably sited, they may hold considerable moisture and also form the head of seepages and associated ephemeral surface streams.

(d) Flares (or waves). These are flat or sloping extensions of the rock surface forming an "edge" which abuts on the apron of soil. Undisturbed outcrops usually have a scatter of exfoliated slabs on the base of the "wave".

(e) Shelves. They are present on most of the domical or higher rocks and even some of the platform types. Depending on the depth of soil deposition, vegetation varies from meadow-type ephemerals, ferns, *Borya,* and rushes to shrubs.

(f) Apron with peripheral meadow. At the edge of the rock, an apron of shallow soil is usually present. Because of the underlying rock floor, these meadows become waterlogged after rain and hence are seasonal (summer-dry) bogs. "Resurrection" plants (Gaff 1981), particularly species of *Borya* that through water loss in summer turn

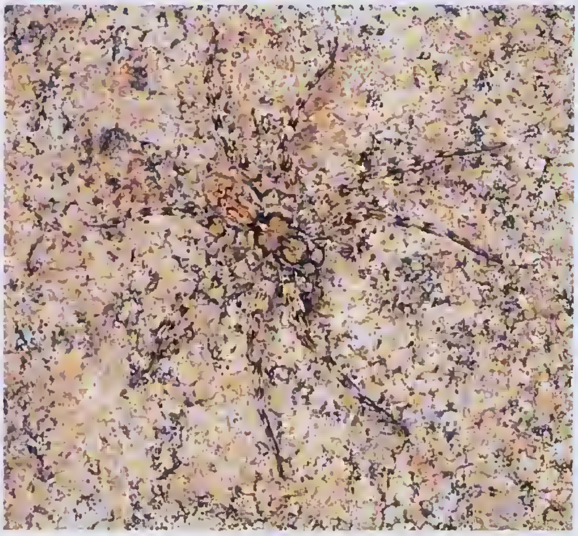

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Plate 1. Exfoliated rock slabs cemented into a wall across the surface of a rock, thereby diverting rainwater from the natural catchment surface and drainage directions into a reservoir (Merredin Rock).

Plate 2. Undisturbed outcrops are generally littered with numerous slabs (exposure near Payne's Find).

Plate 3. Seral meadows are usually small, ranging upwards from about 40 cm to several square metres. They are formed by infilling of rock pools (gnammas) on slopes or flat expanses of outcrops (Sanford Rock).

Plate 4. The rock "carpet" wolf spider, so named because of the carpet-like, mottled pattern (photograph by D Elford).

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orange then green when they rehydrate after rain, are the dominant plants of aprons.

(h) Crevices. These, and vertical cracks, on outcrops frequently shelter mobile invertebrates and occasionally provide a permanent home for sedentary organisms, particularly if soil and debris accumulates. The roots of some shrubs such as *Kunzea*, *Beaufortia* and *Anthocercus* may also penetrate cracks of the rock deep below the perceptible crevice and thus provide further habitat amongst root mats, on bark and foliage.

(i 2) Seral meadows. These meadows are usually small, ranging upwards from about 40 cm to several square metres. They are formed by infilling of rock pools (gnammas) on slopes or flat expanses of outcrops (Plate 3). Depending on their depth they may be vegetated by lichen, moss, ferns, orchids, ephemerals and *Borya*, but occasionally with rushes and small shrubs including *Baeckea*, *Beaufortia* and *Kunzea*.

(g 2) "Babylonian gardens. "Hanging" clumps of vegetation develop in soil that accumulates in tiered gnammas or stepped, pocket-like depressions on the slopes of rocks (see Main 1997, Plate 4). They are thus a late seral stage of the "water fall" sequence of rock pools (g 1).

A specialised and extensive habitat, not discussed here, comprises the algae and thin lichen sheets which mantle the entire surface of granite outcrops. This habitat supports microorganisms that have not been subject to study in the region.

Aquatic habitats

(g 1) Tiers or steps of depressions (gnammas), seasonal rock pools. During and after heavy rain, these develop into cascades or waterfalls.

(i 1) Gnammas or rock pools. These form in depressions of the rock surface and may be shallow (Plate 3) or deep, ranging from a few centimetres in depth to at least a metre. Bayly (1997) and Campbell (1997) discuss the structure and nomenclature of various types of rock holes and pools.

(j) Runoff seeps and streams. Seeps from moss beds, which trickle continuously through the wet season, provide a specialised habitat. Some configurations on rocks also direct runnels of water into localised streams in declivities.

(k) Peripheral creeks. These form around the edges of outcrops and often drain into surrounding bush and woodland. Even when these creeks cease to flow they frequently hold water for long periods in water holes that are able to augment populations of invertebrates beyond the time of the ephemeral rock pools (gnammas).

Habitat occurrences and biology of fauna

There have been few targeted studies of terrestrial invertebrate occurrences on granite outcrops, either as surveys of particular rocks or distribution of particular taxa and their association with a range of rocks. Much of the available information is unrecorded *i.e.* unpublished, or is associated only with taxonomic descriptions. Perhaps the only survey-type study is that of Doronila & Fox (1997), who surveyed the ants of Sandford Rock Nature Reserve. However, in this study only three of the eleven habitat sites surveyed could strictly be regarded as rock or fringing rock habitats. Nevertheless, a substantial number of records have been gleaned from various sources and these are compiled in Table 1.

The aquatic fauna has been subjected to more focused study (Bayly 1982). Bayly (1997) reported on a survey of gnammas on 17 granite outcrops. The biology of a few selected taxa has also been studied either at individual rocks or over their geographic range *e.g.* of chironomid midges including *Archaeochlus* (Jones 1974; Cranston *et al.* 1987; Edward 1989). Again, information obtained from various records is summarised in Table 1.

The precariousness of the overall rock habitat and naturally seasonal drought means that survival of organisms is closely linked to (a) the refugial nature of microhabitats and (b) coincidence of dormant life history stages and unfavourable seasonal conditions. Habitats such as moss swards and those associated with soil and litter accumulation, as on shelves and meadows, are able to absorb moisture from fog as well as rain. Rock surfaces act as catchments even during light rain and mist (Fernie 1930; Laing & Hauck 1997) and some of such water is chanelled into depressions and also captured by moss and lichens. Temperatures on the rock surface can range from over 50 °C (Marchant 1973; Bradshaw & Main 1968) to below zero. Although experiencing extremes of temperature under the flakes, the high temperatures are lower than on the exposed rock surface. Several spider taxa reside permanently under rock flakes; most are web weavers but some are hunting spiders that forage at night thereby avoiding heat stress (as do also their arthropod prey).

A few terrestrial animals are able to burrow *e.g.* mygalomorphs and some lycosid spiders, some scorpions, myriapods particularly millipedes, and insects such as cockroaches. The mygalomorph genus *Teyl* occurs in the meadows of many granite rocks. These spiders aestivate in sealed burrows for months; dispersion of brood young, wandering of males and mating and foraging of spiders takes place during the winter.

Endemicity (*i.e.* restriction to particular rocks) of invertebrates does not appear to be as marked as for plants. Notable known exceptions are in the mygalomorph genus *Teyl* (however the numerous species remain unnamed; Main 1997), the pseudoscorpion *Synsphyronus elegans* Beier which is known only from Yorkrakine Rock (Harvey 1987) and the water mite *Chudalupia meridionalis* from Mt Chudalup (Wallwork 1981). The genus *Teyl* has almost certainly speciated due to isolation around the refugial rocks during onset of arid conditions from late Oligocene through the Pliocene (Main 1999). In contrast many species are widely distributed, even some which are known to occur only on granite rocks. Hence the question arises as to how they are dispersed. While some web-weaving spiders such as the redback (which of course also occurs in other habitats), other theridiids and pholcids disperse on gossamer as spiderlings, the dispersion behaviour of most of the hunting spiders (*Delena* and *Eodelena*, *Rebilus* and *Hemicloea*) is unknown. For spiders and other invertebrate species which are known to occur also in habitats other than granite rocks, such as under bark of

trees in surrounding bushland, their occurrence on the rock "islands" is easily explained.

A spider of particular interest is the rock "carpet" wolf spider, so named because of the carpet-like, mottled pattern (Plate 4). This large, unnamed lycosid attributed to *Pardosa* by Main (1976) may rightly belong taxonomically elsewhere. Believed to comprise a single species, it has been recorded from many widely separated rocks. It lives permanently under exfoliated slabs, hunts on the rock at night and appears to be territorial regarding both home "slab" and foraging terrain. Clearly there is much observational and biological work to be done to unravel some of the biological enigmas associated with evolutionary history and dispersion of invertebrates on rock outcrops.

Aquatic organisms comprise two categories. One group shows definite life history adaptations to summer drought and produce dormant eggs, as do many of the crustacean groups or the organisms are dormant as larvae or pupae (*e.g.* certan dipterans) and thus remain *in situ* in the dried out pools on the rocks, revitalising after rain. The other group have no dormant phase. Some have aquatic larvae and either a terrestrial adult phase (some insects *e.g.* dragonflies) or an adult stage, which is amphibious (certain beetles). Alternatively, water mites for example are dependent on an aquatic habitat throughout life and are transported by other organisms (insects or birds) from one water body to another. Such organisms are clearly not confined to rock pools but, like some of the terrestrial organisms enjoy a multi-habitat life style.

Natural hazards and human impacts

Natural hazards are related to weather and climate, including extremes of temperature, occasional floods and wind storms when organisms can be plucked from their habitats and blown away. However flood and wind can conversely also help to disperse some organisms as Main (1997) noted in reference to aeolian reinforcement of fauna on rocks. Over a long time period the fauna can readjust to natural inimical conditions. In contrast the shorter time scale and abruptness of human impacts does not always allow the fauna to restabilise.

Adverse human impacts include;

(a) direct destruction of habitats and foraging on invertebrates, principally the following:

- removal of rock flakes and slabs or translocation of such rock flakes into retaining walls or simply by overturning the flakes in situ thereby exposing the under-surface and damaging the under-rock niche;
- blocking of natural drainage lines on the rock or peripheral creeks and construction of dams (drowning of rock surface areas and environs of peripheral creeks and depleting water source for natural habitats);
- vehicle damage to moss swards, and algae and lichen crusted rock surfaces;
- damage to rock faces (and lichen/algae crusts) by graffiti;
- haphazard dumping of rubbish in sensitive areas;
- pollution of rock pools by washing of superphosphate bags (and construction of small dams on peripheral creeks for the same purpose);
- damage to habitats by feral animals *e.g.* pigs which overturn rock flakes and uproot vegetation while foraging (personal observations); pollution of water bodies by dogs, foxes, donkeys, camels and horses; burrowing and foraging by rabbits;
- destruction of habitats by hooves and decline of vegetation by grazing animals (sheep and cattle) particularly on private property; and
- foraging on invertebrates by foxes;

and (b) indirect and incremental, additional long term effects such as;

- establishment of weeds through dispersal by feral animals including rabbits (see above), farm animals on private property, and dumping of farm animal carcases;
- depletion of or damage to vegetation through browsing and foraging (feral animals and farm stock);
- damage to the soil/debris interface of microhabitats *e.g.* the fragile floor of rock pools, meadows and the apron by feral animals and farm stock;
- physical damage to rock surfaces (see above, particularly the unstudied algae/lichen sheets) by casual hikers; and
- modification of "aesthetic sites" (usualy flat areas on outer edge of apron meadows) by picnickers for provision of vehicle parking, barbecues, rubbish disposal and toilet facilities. On a larger scale, camping and caravan areas jeopardise similar sites.

Conservation and restoration

It is outside the scope of this paper to itemise management and restoration procedures which have been addressed by AR Main (1997), Hussey (1998) and Anon (1999). However, any management and reconstruction procedures need to take into account that the richest habitats for macroinvertebrates are also the most vulnerable. Rock flakes and slabs and rock pools support a diverse assortment of taxa, while the numbers of species known from various rocks are probably only a small proportion of those present over the array of rocks in southern Western Australia. In settled areas, both in the wheatbelt and pastoral areas, many rocks have lost most of their loose flakes to water catchments and vandalism. Throughout the forest and coastal areas, vandalism is also prevalent.

It is not readily apparent to the non-biologist that seemingly barren rocks actually support an array of living invertebrate animals as well as plants. Even the more obvious seasonal life in the rock pools is frequently disregarded. Again, the rock pools are subject to pollution and vandalism. The invertebrate fauna of the moss and lichen swards is poorly known, but likely to be rich in small crustaceans (*e.g.* amphipods), insect larvae and collembolans, tardigrades and earthworms as well as those organisms noted in Table 1.

While translocation of certain vertebrates to restore populations that have been lost is practical, it is probably

Table 1

A preliminary inventory of invertebrate fauna collected or recorded from, or observed in association with granite outcrops. See Fig 1 for explanation of symbols (a - k) representing particular microhabitats. WAM, database of Western Australian Museum, specimen labels indicating association with granite rocks. BYM (Barbara York Main), unpublished observations, field notebook records or specimens in personal collection. MSH (Mark S Harvey), pers comm (observations).

	HABITAT	AUTHORITY
TERRESTRIAL		
ARACHNIDA		
ARANEAE (SPIDERS)		
MYGALOMORPHAE		
BARYCHELIDAE	(b, e, f)	BYM (Withers & Edward 1997)
IDIOPIDAE		
Aganippe spp	(e, k-banks)	BYM (Withers & Edward 1997)
Gaius sp	(f)	BYM (Withers & Edward 1997)
NEMESIIDAE		
Chenistonia tepperi Hogg	(e, f)	BYM; WAM (Withers & Edward 1997)
Teyl spp	(e, f, i 2)	(Main, 1976,1997; Withers & Edward 1997)
Merredinia damsonoides Main	(f)	BYM (Withers & Edward 1997)
Kwonkan eboracum Main	(f)	(Main 1983; Withers & Edward 1997)
Aname diversicolor Hogg	(f)	BYM (Withers & Edward 1997)
ARANEOMORPHAE		
DESIDAE		
Badumna spp	(b)	BYM
Forsterina spp	(b) ?	WAM
DYSDERIDAE		
Ariadna spp	(e, f, i 2)	BYM (Withers & Edward 1997)
GNAPHOSIDAE		
Hemicloea spp	(b)	BYM
LINYPHIIDAE		
Erigone spp	?	WAM
others		WAM
LYCOSIDAE (wolf spiders)		
Lycosa spp	(a, b, c, e, f, i 2)	BYM
Lycosa leuckartii	(b, e)	BYM
"lycosid" as *Pardosa* sp	(b)	(Main 1976; Withers & Edward 1997)
MITURGIDAE		
Miturga spp	(b, e)	(Main 1976; Withers & Edward 1997)
MIMETIDAE		
Australomimetus sp	(b)	WAM
NICODAMIDAE		
Nicodamus mainae Harvey	(b, e, f, i 2)	(Harvey 1995; Main 1976)
OONOPIDAE		
Opopaea sp	?	WAM
PHOLCIDAE (daddy longlegs)	(a, b)	
Trichocyclus spp ?	(a, b)	BYM
PRODIDOMIDAE		
"*Molycria* spp"	(b)	BYM; MSH; WAM
SALTICIDAE		
Adoxotoma chinopogon Simon	?	WAM
SELENOPIDAE		
Selenops spp	(b)	BYM; MSH
SPARASSIDAE =HETEROPODIDAE (huntsman spiders)		
Delena cancerides Walckenaer	(a, b)	(Main 1976)
Eodelena lapidicola Hirst	(b)	(Hirst 1991; Main 1954 as *Delena cancerides*)
STIPHIDIIDAE		
Baiami sp	(b, e)	BYM; WAM
Corasoides spp	(i 2, e, f)	BYM
THERIDIIDAE		
Latrodectus hasselti Thorell	(a, b)	(Main 1976; Withers & Edward 1997)
Steatoda spp	(b)	BYM; MSH
other genera	(b)	BYM; MSH
TROCHANTERIIDAE		
Rebilus spp	(b)	BYM (Bayly 1992; Main1976; Withers & Edward 1997)

Table 1 (continued)

	HABITAT	AUTHORITY
SCORPIONIDA		
SCORPIONIDAE		
Urodacus planimanus Pocock	(b, b/e)	WAM (Koch 1977)
Urodacus sp	(b, b/e)	BYM
BUTHIDAE		
Lychas marmoreus (Koch) ?	(b)	BYM
PSEUDOSCORPIONIDA		
GARYPIDAE		
Synsphyronus elegans Beier	(b)	BYM; WAM (Beier 1954; Harvey 1987; Withers & Edward 1997)
S. callus Hoff	(b)	MSH
S. gigas Beier	(b) ?	(see Harvey 1987)
S. leo Harvey	(b)	(Harvey 1987)
Synsphyronus spp	(b) ?	BYM; MSH
OPILIONIDA (harvestmen)		
CADDIDAE		
Hesperopilio mainae Shear	(e, f)	BYM; WAM (see Shear 1995)
TRIAENONYCHIDAE		
Calliuncus sp	(e)	BYM
Nunciella aspera (Pocock)	(b)	BYM; WAM (Main 1954 ?)
ACARI		
TROMBICULIDAE		
Schoengastia gutekunsti Goff	(b ?)	BYM; WAM
MYRIAPODA		
CHILOPODA (Centipedes)		
Cormocephalus hartmeyeri Kraepelin	(b)	BYM; MSH; WAM
Scolopendra morsitans Linnaeus	(b, f)	BYM
Scolopendra laeta	(b ?)	BYM
GEOPHILIDA	(b, e)	BYM; WAM
DIPLOPODA		
SPHAEROTHERIIDAE		
Cynotelopus notabilis Jeekel	(b, e)	BYM; WAM
PARADOXOSOMATIDAE		
Antichiropus spp	(b, e, f)	BYM; MSH
ONYCOPHORA		
PERIPATOPSIDAE		
Occiperipatoides gilesii (Spencer)	(c, e, f ?)	BYM; WAM
CRUSTACEA		
ISOPODA	(b, e, f, g 2)	BYM
AMPHIPODA	(c, e, g 2, h)	BYM
INSECTA (a selection)		
(There are undoubtedly many additional specimen records in the WAM and Australian National Insect Collection, CSIRO, Canberra and records scattered through the taxonomic literature; however difficulty of access and time constraints have not allowed thorough documentation for this preliminary account).		
Various orders including:		
BLATTODEA (cockroaches)	(b)	BYM
COLEOPTERA	(b, e)	BYM
TENEBRIONIDAE (Piedish beetles)	(b)	BYM
CARABIDAE	(b)	BYM
DERMAPTERA (ear wigs)	(b, e)	BYM
DIPTERA		
STRATIOMYIDAE	(j/f)	BYM
EMBIOPTERA	(a, b)	BYM; (Ross 1991; Withers & Edward 1997)
HEMIPTERA		
REDUVIIDAE	(b)	BYM, MSH
HYMENOPTERA		
ants	(a, b, c, e, f)	BYM
mud wasps	(a, b, h)	BYM (Main 1967; McMillan & Pieroni undated)
LEPIDOPTERA (moth larvae)	(c)	(Main 1967)
ORTHOPTERA (crickets, grasshoppers)	(b, c)	BYM

Table 1 (continued)

	HABITAT	AUTHORITY
AQUATIC		
Selected higher taxonomic categories (Orders & Families) only are given if listed by Bayly (1997, Table 2) for taxa from rock pools (habitat (i 1) as defined here). See also Bayly 1992; Hussey 1998; Main 1967; McMillan & Pieroni undated; and other authorities listed below.		
ARACHNIDA		
ACARI (water mites)		
ORIBATEI	(i 1)	(Bayly 1997)
AMERONTHIIDAE		
Chudalupia meridionalis Wallwork	(i 1)	(Wallwork 1981)
ARRENURIDAE		
Arrenurus balladoniensis Halik	(i 1)	MSH
CRUSTACEA		
ANOSTRACA (fairy shrimps)	(i 1)	(Bayly 1997; Main 1967; McMillan & Pieroni undated)
CLADOCERA (water fleas)	(i 1)	(Bayly 1997; Hussey 1998; Main 1967; McMillan & Pieroni undated)
CONCHOSTRACA (clam shrimps)	(i 1)	(Bayly 1997; Main 1967; McMillan & Pieroni undated)
COPEPODA (copepods)	(i 1)	(Bayly 1997; Main 1967)
NOTOSTRACA (shield shrimps)	(i 1)	(Bayly 1997; Main 1967)
OSTRACODA (seed shrimps)	(i 1)	(Bayly 1997; Hussey 1998; Main 1967; McMillan & Pieroni undated)
INSECTA (larval and/or adults)		
DIPTERA		
CERATOPOGONIDAE	(i 1)	(Bayly 1997; McMillan & Pieroni undated)
CHIRONOMIDAE	(i 1)	(Bayly 1997; Main 1967; McMillan & Pieroni undated)
Archaeochlus Brundin	(j)	(Cranston, Edward & Colless 1987; Edward 1989)
GERRIDAE	(i 1, k)	(McMillan & Pieroni undated)
COLEOPTERA		
DYTISCIDAE	(i 1)	(Bayly 1997; Main 1967; McMillan & Pieroni undated)
GYRINIDAE	(i 1)	(McMillan & Pieroni undated)
HYDROPHILIDAE	(i 1)	(Bayly 1997; McMillan & Pieroni undated)
HEMIPTERA		
CORIXIDAE	(i 1)	(Bayly 1997; Hussey 1998; Main 1967; McMillan & Pieroni undated)
NOTONECTIDAE	(i 1)	(Bayly 1997; McMillan & Pieroni undated)
ODONATA	(i 1)	(Main 1967; Hussey 1998; McMillan & Pieroni undated)
TRICHOPTERA (caddis flies)	(i 1, k)	(Main 1967)
PLATYHELMINTHES	(i 1)	(Main 1967; Bayly 1997)
NEMATODA	(i 1)	(Bayly 1997)

Note: dominant habitats are the most vulnerable; predominantly rock pools (i 1) & rock flakes (b); run off seeps (j) important for relictuals.

not an option for invertebrates except possibly for some of the larger species (spiders and myriapods). Restoration and protection of habitats would seem to be the immediate pragmatic approach.

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